Short note

Physicochemical characteristics of binary mixtures of camel hump fat and citrus seed oil

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The current investigation aimed to evaluate the physicochemical characteristics of camel hump fat (CHF), citrus seed oil (CSO) and their binary mixtures. CHF: CSO blends were prepared in six ratios: 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 (w/w). The native and blended oils were evaluated in terms of their fatty acid composition, lipid quality indices, cholesterol content and some physicochemical characteristics. CHF mainly contains saturated fatty acids (63.40%) and monounsaturated fatty acids (34.68%) and a small amount of polyunsaturated fatty acids (1.92%). The most prominent fatty acids in CSO were linoleic (37.54%), oleic (25.36%) and palmitic (26.56%) acids which accounted for 89.46% of the total fatty acids. Substitution of 20, 40, 60 and 80% of CHF with equivalent quantities of CSO reduced the content of saturated fatty acids by 8.61, 19.27, 29.35 and 38.24%, respectively in blended oils. The content of polyunsaturated fatty acids increased from 1.92% in CHF to 8.99, 17.68, 25.87 and 33.40 in CHF blended with 20, 40, 60 and 80% of CSO, respectively. Atherogenic index values of CHF blended with 60 and 80% of CSO were about 2.37 and 3.23 times as low as this of CHF, respectively. The physico-chemical properties of the native oils were changed. The refractive index increased from 1.4590 in CHF to 1.4745 in CHF blended with 80% (w/w) of CSO. Melting point shifted to lower values from 78.0°C in CHF to 65.0, 50.5, 36.0 and 22.0°C in CHF blended with 20, 40, 60 and 80% of CSO, respectively. No significant differences were observed in specific gravity among native and blended oils. Colour values of CHF blended with 60 and 80% of CSO were about 1.45 and 1.70 times as low as of CHF, respectively. Blending CHF with 20, 40, 60 and 80% of CSO caused significant decreases in viscosity values by 6.06, 13.13, 21.21 and 28.28%, respectively in the blended oils. Acid value decreased from 0.99 for CHF to 0.78 (20 CHF: 80 CSO) blend oil. Peroxide values of CSO blended with 40, 60 and 80% of CHF were about 1.20, 1.36 and 1.50 times as low as that of citrus seed oil, respectively. Saponification number decreased from 203.1 mg KOH/g oil in CHF to 191.49 mg KOH/g oil in CHF mixed with 80% of CSO. Iodine value increased from 63.50 gI2/100 g for CHF to 71.00, 79.08, 85.56 and 93.02 gI2/100 g in CHF blended with 20, 40, 60 and 80% of CSO, respectively.

Keywords: camel hump fat, citrus seed oil, binary mixtures, physicochemical characteristics, fatty acids.

INTRODUCTION

Most vegetable fats and oils have restricted applications in their original configurations, because of their specific fatty acid (FA) compositions. Several studies proved that the physicochemical characteristics and nutritional properties of lipids are determined by their fatty acid composition. The physiochemical characteristics of oils and fats are affected by numerous factors, such as solid fat content (SFC), the composition of triacylglycerol and the polymorphic behavior of their crystals [1]. Modifying the natural physicochemical properties of fat or oil, can be used to give fats and oils desirable characteristics. The uses of fats and oils can be expanded by modifying their properties through genetic engineering of oil crops, interesterification, blending, fractionation, hydrogenation, or combinations of these operations [2,3]. Blending less stable vegetable oils with more stable fats or oils improves their quality and stability as well as produces value-added fats and oils [4]. Blending of oils is one of the simplest procedures to produce new specific formulas. Mixing different types of oils not only can modify the profile of fatty acids, but also improve the amounts of bioactive components in the blended oils and provide better quality oils, allowing the production of a better formula with desirable quality attributes as well as improves nutritional attributes at affordable prices [5, 6, 7]. Citrus fruits are of prime economic importance because of their multiple uses, such as in the food industry, cosmetics, and folk medicine [8, 9, 10]. Citrus fruits such as orange, grapefruit, lemon, tangerine, shaddock, sour orange, citron, and lime are processed to produce natural juice and the fruit wastes such as peels, seeds and pulp are a potential source of valuable by-products, generated in large amounts, which represent about 50% of the weight of raw processed fruit [11]. The citrus seeds, commonly considered as agro-industrial waste, are a potential source of oil. These seeds contain from 26 to 42% of oil and are a good source of carotenoids, phenolics, tocopherols, and phytosterols [11, 12]. The main fatty acids of the mixture of Egyptian citrus seed oil were palmitic acid (28.54%), oleic acid (24.53%), and linoleic acid (38.25%) [11]. Anwar et al. [12] reported the following physico-chemical characteristics of Pakistani citrus seed oils: iodine value varied 99.9 to 110.0; saponification value ranged from 180.9 to 198.9; unsaponifiable matter ranged from 0.3 to 0.5%; acid value (mg KOH/g of oil), ranged from 0.5-2.2; refractive index at (40°C), ranged from 1.4639-1.4670; density (24°C) ranged from 0.920 to 0.941 mg/mL; and the range of colour was (1-in. cell) 1.4-3.0 R + 15.0-30.0 Y. Animal fats are lipid substrates derived from animal tissues. In this regard, camels occupy an important position in Africa, Middle East and Asia because they provide milk, meat and fat for humans [13, 14, 15]. Edible camel hump fat used for cooking or sometimes not used and then becomes waste, contains cholesterol (37-39 mg/100 g). Total contents of saturated fatty acids and unsaturated fatty acids of camel hump fat were 60.30 and 39.70%, respectively [16]. The main fatty acids of the camel hump fat were palmitic acid (32.5%), stearic acid (18.95%) and oleic acid (37.20%) [16]. Dietary lipids play a vital role in diet and health. They supply energy and essential fatty acids, act as carriers of fat soluble vitamins, as well as enhance the acceptability of the food. Epidemiologic studies show that a diet high in saturated fatty acids has been correlated with chronic diseases of the cardiovascular system [17]. On the other hand, a diet with a suitable amount of unsaturated fatty acids may have a positive effect on the prevention of chronic heart disease. Therefore, the analysis and the type of fatty acids in foods are essential for nutritional and health purposes [18]. The aim of the current study was to investigate the changes in the physicochemical characteristics of binary mixtures of camel hump fat and citrus seed oil.

MATERIALS AND METHODS

MATERIALS

The orange seeds (*Citrus sinensis*) of balady variety, mandarin*(Citrus mitis)* and grapefruit (*Citrusparadisi*) were collected from a private company, Giza, Egypt during the winter season of 2015. The citrus seeds were washed several times with tap water to remove foreign substrates and sun- dried on trays for 5 days. Dried seeds were packed in plastic bags and stored in a freezer (- 25°C) until further use. Camel hump fat samples were purchased from a slaughter house, Giza, Egypt. The samples were cleaned, washed, cut into small pieces, and stored in polyethylene bags at 25°C until further analysis. All chemicals used in the current study were of analytical grade.

EXTRACTION OF OIL CONTENT FROM CITRUS SEEDS

Citrus seeds subjected to the current investigation were ground using an electric grinder (Panasonic, Model, MX-AC210SWUA), until obtaining a fine powder. The ground seeds were extracted with n-hexane (BP, 67°C) for 96 h using the cold extraction. Hexane solvent was removed by vacuum evaporation using rotary evaporator at 45°C. The oil was centrifuged at 4000 rpm for 1h and vacuum filtered through a cotton filter cloth. The obtained oil was stirred with the anhydrous sodium sulphate for 30 min, and then vacuum filtered through a cotton filter cloth. Filtrated oil was kept in glass containers, and stored at - 25°C until further use.

EXTRACTION OF LIPIDS CONTENT FROM CAMEL HUMP FAT

Chopped camel hump was heated at 95°C for 5 h. Extracted fat was separated from camel hump tissue by filtration through a cotton filter cloth.

PREPARATION OF BLENDED OILS

Both citrus seed oil and camel hump fat were blended at the ratios of 0:100, 20:80, 40:60, 60:40, 80:20 and 100:0 (w/w), respectively. Camel hump fat/citrus seeds oil blends were individually stirred using a magnetic stirrer for 1 h at 50°C, placed into a clean, dry, 250 mL round-bottomed glass containers, and stored at – 25°C until further use.

ANALYTICAL METHODS

FATTY ACID COMPOSITIONS OF NATIVE AND BLENDED OILS

The determination of fatty acid profile was conducted using capillary gas chromatography (HP 6890). Fatty acid methyl esters (FAMEs) were assessed and identified by the method described by according the previous procedure described by Ali and El-Anany [4].

LIPID QUALITY INDICES

The atherogenicindex (AI) and thrombogenic index (TI) were calculated using the suggested equations of Ulbricht and Southgate[19] (1991) as follows:

AI = (C12:0 + 4 × C14:0 + C16:0)/(MUFA + PUFA)

TI = (C14:0 + C16:0 + C18:0)/(0.5 × MUFA + 0.5 × n-6 PUFA + 3 × n-3 PUFA + n-3/n-6 PUFA)

where:
MUFA, Monounsaturated Fatty Acids; PUFA, Polyunsaturated Fatty Acids.

CHOLESTEROL CONTENT

Cholesterol was determined in triplicate according to the previous procedure described by Ojiako and Akubugwo [20].

PHYSICOCHEMICAL CHARACTERISTICS OF NATIVE AND BLENDED OILS

REFRACTIVE INDEX

The refractive index was determined according to the AOAC method (977.17) [21].

SPECIFIC GRAVITY

The specific gravity of oil samples was determined according to the AOCS method Cc 10a25 [22].

MELTING POINT

The melting point of oil samples was determined according to the AOCS method Cc 1-25 [23].

COLOUR

The colour of the oil samples was measured using Lovibond tintometer. The yellow glass filter was fixed at 30 and the intensity of the red glass colour was measured [4].

VISCOSITY

Brookfield LV viscometer Model TC-500 (Brookfield Engineering Laboratories Stoughton, MA, USA) was used to determine the viscosity of the oil samples at 45°C, according to the method described by Saguy et al. [25].

ACID VALUE

Acid value was determined according the AOAC [21]. Method (969.17) Acid value is expressed as mg KOH/1 gram of fat or oil sample.

PEROXIDE VALUE

Peroxide value was determined according to the standard procedures of AOAC [21], method (965.33). Peroxide value is expressed as milliequivalent peroxides/kg of fat or oil.

IODINE VALUE (IV)

The iodine value of oil samples was determined using the Hanus method according to the AOCS method 920.158 [26] (2000). Iodine value is expressed as gram of I_2 absorbed by 100 g oil.

SAPONIFICATION VALUE

Saponification value of oil samples was determined according to the AOAC method (920.160) [21].

STATISTICAL ANALYSIS

Data are expressed as mean ± standard deviation (SD). Data were subjected to statistically analysis according to the procedures described by Gomez and Gomez [27]. SPSS Version 18.0 (SPSS Inc., Chicago, IL, USA) was used to analyse data.

RESULTS AND DISCUSSION

Fatty acid compositions, lipid quality indices and cholesterol content of camel hump fat (CHF), citrus seeds oil (CSO) and their binary mixtures are shown in Table I. Camel hump fat mainly contains saturated fatty acids (63.40%) and monounsaturated fatty acids (34.68%) and a small amount of polyunsaturated fatty acids (1.92%).The most commonly fatty acids present in camel hump fat are oleic (34.68%) and palmitic (28.75%) acids followed by stearic (20.95%) and myristic (11.50%) acids, which together presents 95.88% of the total fatty acid. These findings agree well with those reported by Elsanhoty et al. [16] for the Saudi Arabian camel hump fat, Shibani el al. [28], for adipose tissues from single-humped Arabian camel and Sbihi et al. [29] for fat from the hump of young camels (Hachi). The most prominent fatty acids in citrus seeds oil were linoleic (37.54%), oleic (25.36%) and palmitic (26.56%) acids which accounted for 89.46% of the total fatty acids. The contents

Table I - Fatty acid compositions (%), lipid quality indices and cholesterol content of camel hump fat (CHF), citrus seed oil (CSO) and binary mixtures of them

			CHF : CSO (v/v)			
Fatty acid	**CHF**	**CSO**	**80:20**	**60:40**	**40:60**	**20:80**
Caprylic (C8:0)	ND	0.89	ND	ND	0.51	0.72
Capric (C10:0)	0.85	ND	0.68	0.48	ND	ND
Lauric (C12:0)	1.35	0.75	1.27	1.15	0.97	0.89
Myristic (C14:0)	11.50	0.55	9.30	7.24	4.96	2.78
Palmitic (C16:0)	28.75	26.56	29.01	27.91	27.50	27.30
Stearic (C18:0)	20.95	4.40	17.68	14.40	10.85	7.46
Oleic (C18:1)	34.68	25.36	33.07	31.14	29.34	27.45
Linoleic (C18:2)	1.92	37.54	8.07	16.06	23.48	30.0
Linolenic (C18:3)	ND	3.95	0.92	1.62	2.39	3.40
ΣSFA	63.40	33.15	57.94	51.18	44.79	39.15
ΣMUFA	34.68	25.36	33.07	31.14	29.34	27.45
ΣPUFA	1.92	41.49	8.99	17.68	25.87	33.40
Lipid quality indices and cholesterol						
Atherogenic index (AI)	2.07	0.44	1.60	1.18	0.87	0.64
Thrombogenic index (TI)	3.34	0.722	2.40	1.74	1.28	0.96
Cholesterol (mg/kg)	1009.85	ND	808.75	606.00	404.80	203.00

ND: refers to not detected; SFA: refers to saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids.

of saturated fatty acids, monounsaturated fatty acids polyunsaturated fatty acids in citrus seeds oil were 33.15, 25.36 and 41.49% of total fatty acids, respectively. These findings indicate that citrus seeds oil can be regarded as linoleic-oleic oil because of the abundance of linoleic acid (37.54%) followed by oleic acid (25.36%). Egyptian citrus seed oils had considerable amounts of unsaturated fatty acids which composed mainly of linoleic (33.2%-38.4%) followed by oleic (22.3-26.0%) and linolenic (2.6%-9.6%) acids [11]. In this regard, the major fatty acid of the Turkish citrus seed oil was oleic (12.8-70.1%), followed by linoleic (19.5-58.8%) and palmitic (5.1-28.3%) acids [30]. Fatty acid compositions of the blended oils are listed in Table I. Differences in the fatty acid compositions were due to the difference in the blending ratios between the native oils under investigation. The results show that addition of CSO to CHF decreased the content of saturated fatty acids in the blended oils. Maximum level of saturated fatty acids (63.40%) was found in CHF. Blended oils contain lower amounts of saturated fatty acids. Replacement of 20, 40, 60 and 80% of camel hump fat with equivalent quantities of citrus seed oil reduced the content of saturated fatty acids by 8.61, 19.27, 29.35 and 38.24%, respectively in blended oils. Citrus seeds oil contains the highest content of polyunsaturated fatty acids (41.49%) and camel hump fat is very poor in polyunsaturated fatty acids (1.92%). Blending camel hump fat with different levels of citrus seed oil caused marked increases in the content of PUFA in the blended oils. Polyunsaturated fatty acids can have positive impacts on the control of cardiovascular disease when consumed in moderation and when used to replace saturated fatty acids in the diet [31, 32]. The content of polyunsaturated fatty acids increased from 1.92% in camel hump fat to 33.40 in camel hump fat mixed with 80% of citrus seed oil. These increases attributed to the fact that citrus seeds oil is rich in polyunsaturated fatty acids (41.49%) (Tab. I). Data for lipid quality indices of camel hump fat (CHF), citrus seed oil (CSO) and their binary mixtures are shown in Table I. Atherogenic index of the native and blended oils under study ranged from 0.44 to 2.07. Camel hump fat had the highest value (2.07) of atherogenic index. Evidence suggests that a high intake of saturated fatty acids (SFA) from the diet may be associated with a high cardiovascular disease risk [33]. Among the saturated fatty acids (SFAs), lauric acid (C12:0), myristic acid (C14:0) and palmitic acid (C16:0), are recognised as health risk factors [33]. From a nutritional standpoint, it has been reported that C18 SFA has a neutral health effect, while C4 to C10 SFAs have positive effects and C12 to C16 SFAs have negative health effects [34]. In particular, SFAs C14-C16 are considered dangerous because they are associated with high serum LDL-cholesterol concentrations in human subjects [35]. However, the lowest value (0.44) of the atherogenic index was recorded for citrus seeds (Table I). Fatty acids can promote or prevent atherosclerosis and coronary thrombosis because of their effects on serum cholesterol and low-density lipoprotein-cholesterol concentrations. Fats not only provide energy in the diet, but also have an important role in promoting good health in humans [33, 36].

Atherogenic index (AI) values of camel hump fat blended with 20, 40, 60 and 80% of citrus seed oil were about 1.29, 1.75, 2.37 and 3.23 times as low as those of camel hump fat, respectively. Particularly, unsaturated fatty acids are considered functional food compounds because of their positive impacts on disease prevention. The ω-6 and the ω-3 fatty acids have demonstrated potential health benefits [37], by reducing the risk of cardiovascular disease [38, 39]. Index of thrombogenicity shows the tendency to form clots in the blood vessels. This is defined as the relationship between the pro-thrombogenetic (saturated) and the anti-thrombogenetic fatty acids (MUFAs, PUFAs–n6 and PUFAs–n3) [40, 41]. The results presented in Table I show the thrombogenic indices of camel hump fat (CHF), citrus seed oil (CSO) and binary mixtures of them.

Thrombogenic indices of native and blended oil varied from 0.96 to 3.34. The highest value of thrombogenic index (3.34) was recorded for camel hump fat. Lauric (C12:0), myristic (C14:0) and palmitic (C16:0) SFAs show a tendency to increase the haematic cholesterol concentration (myristic is more atherogenic), while there is a strong relation between the sum of three fatty acids (myristic, palmitic and stearic) and the thrombus formation [33]. Blended oils have lower thrombogenic index values than camel hump fat as a native fat. The lowest thrombogenic index value (0.96) was recorded for citrus seed oil. The effects of dietary fats on the risk of coronary artery disease (CAD) have traditionally been estimated from their effects on serum total cholesterol [42, 43].

Number of epidemiological studies showing an inverse association between dietary intake of unsaturated fatty acids, conjugated linoleic acid (CLA) and cardiovascular disease [4, 44, 45].

Cholesterol content (mg/kg) of camel hump fat (CHF), citrus seed oil (CSO) and binary mixtures of them ranged not-detectable level to 1009.85. The highest level of cholesterol was recorded for camel hump fat. Cholesterol is the primary animal fat sterol and is only found in vegetable oils in trace amounts. Vegetable oil sterols collectively are termed ‘phytosterols’. Sitosterol and stigmasterol are the best-known vegetable oil sterols [46].

No cholesterol content was detected in citrus seeds oil. Cholesterol content of camel hump fat was higher than that of blended oils and citrus seeds oil. Blending camel hump fat with different levels of citrus seeds oil caused marked decreases in cholesterol contents. Substitution of 60 and 80% of camel hump fat with equivalent amounts of citrus seeds oil reduced the content of cholesterol by 59.912 and 79.89%, respectively in blended oils. Several methods have been conducted to reduce food cholesterol such as blending of vegetable oils, extraction by organic solvent, degradation by cholesterol oxidizers, extraction by supercritical carbon dioxide and byusing cross-linked β-Cyclodextrin (βCD) [16, 47, 48]. These findings attributed to the fact that citrus seed oil is free of cholesterol (Tab.I).

PHYSICOCHEMICAL CHARACTERISTICS OF CAMEL HUMP FAT (CHF), CITRUS SEED OIL (CSO) AND BINARY MIXTURES OF THEM

Refractive index

The refractive index of animal and vegetable oils and fats is sensitive to their composition. The refractive index is a property that relates to the unsaturation degree, fatty acid chain length, and conjugation degree [49]. Figure 1A shows changes in the refractive index of camel hump fat (CHF), citrus seed oil (CSO) and their blends. Refractive index of native and blended oil varied from 1.4590 to 1.4781. Camel hump fat had significantly ($p \leq 0.05$) the lowest value (1.4590) of the refractive index, while citrus seed oil had significantly ($p \leq 0.05$) the highest (1.4781) refractive index value. Incorporation of citrus seed oil into camel hump fat caused significant increases in refractive indices. The increase in refractive index increased gradually and significantly with the increase of incorporation levels. The refractive index of oil blends ranged from 1.4635 in camel hump fat blended with 20% (*w/w*) of citrus seeds oil to 1.4745 in camel hump fat supplemented with 80% (*w/w*) of citrus seeds oil. These increases may be attributed to the increase of the unsaturation degree in blended oils.

The refractive index increases with the increase of the unsaturation and fatty acid chain length. Measurements of the refractive index can therefore be used to monitor processes that involve a change in the composition of fats and oils [50, 51].

Melting point

A melting point is a parameter used to measure the hardness state of fats and oils. A melting point is the temperature at which the fat or oil is completely turned into a clear and transparent liquid [52].

A melting point is one of the oil quality monitors that can be used to regulate the process that involves a change in the formulations of fats and oils [53]. Melting temperatures of native and blended oils are illustrated in Figure 1B. Melting points of native and blended oil ranged from 7.0 to 78.0°C. The highest melting temperature was recorded for camel hump fat, while the lowest one was recorded for citrus seed oil. The melting point of the hump fats of the Arabian camel varied from 77.5 to 82.4°C, these differences in melting point can be attributed to the variations in fatty acid compositions [54]. In this regard, El-Adawy et al. [11] reported that the melting point of Egyptian citrus seeds oil was 7.0°C. Differences in melting points may be attributed to the fact that unsaturated fatty acids have lower melting temperatures than saturated fatty acids of the same length. Because double

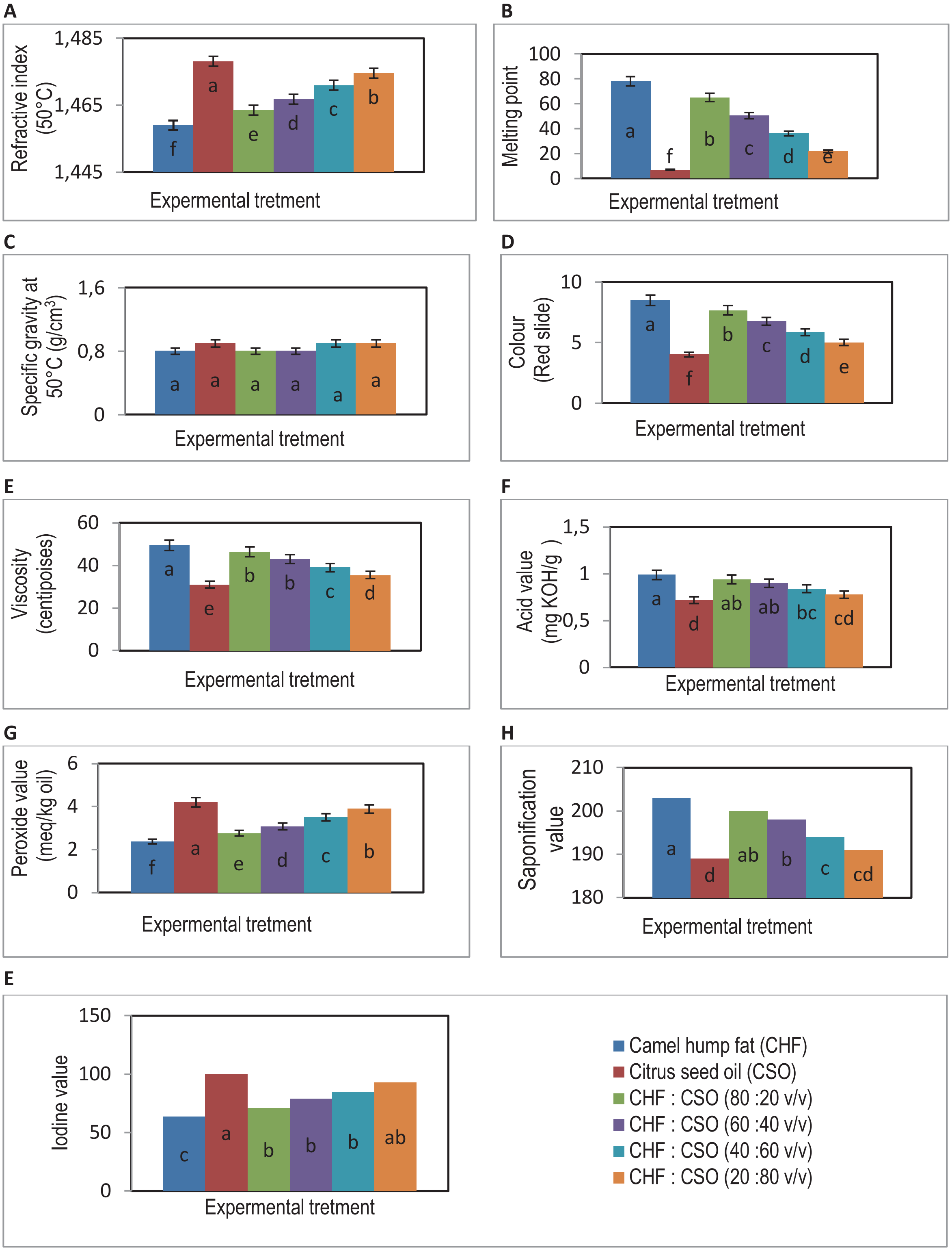

Figure 1 - Physicochemical characteristics of camel hump fat (CHF), citrus seed oil (CSO) and binary mixtures of them. Values with different letters are significantly different (p <0.05).

bonds cause the hydrocarbon chain to bend. Therefore, the fatty acids cannot compact tightly together, reducing the van der Waals interaction between the fatty acids [55].

Blending camel hump fat with various amounts of citrus seed oil caused significant decreases in melting point temperatures of the blended oils. The decrease in the melting point gradually and significantly ($p \leq 0.05$) increased with the increase of the substitution levels with citrus seed oil. The ratio between solid and liquid phases at different temperatures determines the solid fat content (SFC). The changes in the composition of fatty acids in the blended oils resulted in significant changes in melting point values of the obtained oils [56]. Melting point decreased significantly from 78°C in camel hump fat to 65.0, 50.5, 36.0 and 22.0°C in camel hump fat supplemented with 20, 40, 60 and 80% of citrus seeds oil, respectively.

These decreases in the melting point temperature can be explained with the decrease of saturated fatty acid content and increase in the portions of the unsaturated fatty acids in the blended oils. To decrease the melting temperature of fat and oils as well as and to maintain its aesthetic quality, the blending process has received much interest in the edible oil industry as an alternative option to improve the physical characteristics of fats and oils [57].

Specific gravity

Specific gravity measurements of camel hump fat (CHF), citrus seed oil (CSO) and their binary mixtures are shown in Figure 1C. Specific gravity of the native and blended oils under study ranged from 0.8720 to 0.9210. No significant ($p \geq 0.05$) differences were observed in specific gravity among native and blended oils (Fig.1C). The specific gravity of the fats and oils is less than 1 (about 0.86-0.92) and, therefore, they float on the water surface. Solid fats (with high portions of saturated fatty acids) are lighter than the liquid fats (rich in unsaturated fatty acids). Generally, either the unsaturation of the fatty acid chains increase or an increase in the chain length of the fatty acid residues tend to increase the specific gravity [58]. In this regard, the specific gravity of citrus seed oil ranged from 0.912 to 0.923 [59].

Colour

Colour is one of the important physical properties that has a great impact on consumer acceptability [60]. Pure fatty acids are colourless and devoid of spectral characteristics in the visible range. While, all-natural fats and oils contain pigments, which have more or less characteristic absorption patterns (Gupta, 2005). Figure 1D shows changes in the colour (red slide) of camel hump fat (CHF), citrus seed oil (CSO) and their blends. The colour of native and blended oils varied from 4.00 to 8.50 (red glass slides).

The highest value (8.50) of was recorded for camel hump fat; however, the lowest value (4.00) was recorded for citrus seed oil. The darker colour of camel hump fat may be attributed to the fact that phosphatides of fats can degrade and cause dark colours when fats are heated during the extraction process [61]. Regarding, the lighter colour of citrus seed oil, El-Adawy et al. [11] suggested that the oil of Egyptian citrus seeds can be used without further bleaching or decolourisation process. Blending camel hump fat with different levels of citrus seed oil caused significant decreases in the colour values of the blended oils. Colour values of camel hump fat blended with 20, 40, 60 and 80% of citrus seed oil were about 1.11, 1.25, 1.45 and 1.70 times as low as of camel hump fat, respectively.

Viscosity

Viscosity is one of the most commonly used physical parameters to evaluate the quality of edible fats and oils. Viscosity values estimate oil's relative thickness or resistance to flow [49]. The changes in viscosity of camel hump fat (CHF), citrus seed oil (CSO) and their binary mixtures are shown in Figure 1E.

Viscosity values of native and blended oils ranged 31.0 to 49.50 centipoises. Camel hump fat had significantly the highest (49.50) value of viscosity, this can be directly related to the contribution of saturated fatty acids [62], while the lowest value (31.00) was recorded for citrus seed oil. The unsaturation degree of fatty acids and their molecular size influence the kinematic viscosity. In particular, a decrease in the oil kinematic viscosity was distinctly observed with increasing of double bonds in the chain [63]. Consumers demands for oils with lower values of viscosity, density, and low melting point. Fats and oils with desirable viscosity can be obtained by blending process [57]. Blending camel hump fat with citrus seed oil caused significant decreases in viscosity values in blended oils. Several studies indicated that viscosity of fats and oils decreased markedly with decreasing the contents of MUFA and PUFA [64, 65].

Acid value

Acid value is one of common chemical parameters that determine the quality of fats and oils in the specification of fats and oils. This parameter is a measure of the free fatty acids (FFA) in the fat or oil. Figure 1F illustrates the changes in acid value (mg KOH/g oil) of native and blended oils. The acid values of camel hump fat, citrus seed oil, and their binary mixtures ranged from 0.72 to 0.99 mg KOH/g oil. This finding indicates that the fats under study have low lipolytic activity and good stability against hydrolysis. Acid value of virgin fats and oils should not exceed 4 mg KOH/g fat or oil [66]. Therefore, the free fatty acid values of native samples were within the acceptable limit. The highest value (0.99 mg KOH/g oil) was recorded for camel hump fat. However, the lowest acid value was recorded for citrus seed oil (0.72 mg KOH/g oil). El-Adawy et al. [11], reported that the acid value of citron, orange, mandarin, and mixed citrus seed oils were 0.95, 0.67, 1.12 and 0.76 mg KOH/g oil, respectively. Blending camel hump fat with 80% of citrus seed oil caused significant ($p \leq 0.05$) decreases in acid values by 21.21% in blended oils. However, substitution of 20% of camel hump fat with equivalent amounts of citrus seed oil caused slight decrease (5.05%) in the acid value of the blended oil.

Peroxide value

The peroxide value measures the presence of primary oxidation products (i.e., hydroperoxides molecules) in fat and oil samples and may provide indications about the quality and oxidative stability of oil samples. Figure1G demonstrates the changes in peroxide value (meq/kg) of native and blended oils. Peroxide values of camel hump fat, citrus seed oil and their binary mixtures varied from 2.37 to 4.20 meq/kg. The highest peroxide value (4.20 meq/kg) was recorded for citrus seed oil. El-Adawy et al. [11], reported that the peroxide value of citron, orange, mandarin, and mixed citrus seed oils were 5.95, 6.37, 5.90 and 5.98 meq/kg oil, respectively. On the other hand, camel hump fat has significantly ($p \leq 0.05$) the lowest (2.37 meq/kg) peroxide value. These differences in peroxide values can arise from various factors such as the presence of unsaturated fatty acids in a triacylglycerol molecule, storage conditions, exposure to light, and metal contents or other compounds that may catalyse the oxidation processes [67]. Unsaturated fatty acids react with oxygen especially in the presence of metals and produce hydroperoxide molecules [51]. Substitution of 20, 40, 60 and 80% of citrus seed oil with equivalent amounts of camel hump fat caused significant reductions in peroxide value in blended oils. Peroxide values of citrus seed oil blended with 40, 60 and 80% of camel hump fat were about 1.20, 1.36 and 1.50 times as low as that of citrus seed oil, respectively. These results indicate that the peroxide values of camel hump fat, citrus seed oil and their binary mixtures meet the limits of peroxide value specified by the Codex Alimentarius, Codex Stan 210 [66].

Saponification value

The saponification value indicates the amount of saponifiable units (acyl groups) per unit weight of oil. A high saponification value indicates a higher proportion of low molecular weight fatty acids in the oil or vice versa [68]. The saponification value is used to measure the average molecular oil weight and expressed in milligrams of potassium hydroxide (mg KOHg/oil). The saponification values of camel hump fat, citrus seed oil and their binary mixtures are shown in Figure 1H. The SV of the native and blended oils varied from 188.5 to 203.1 mg KOH g^{-1} oil. The highest saponification value (203.1 mg KOH g/oil) was recorded for the camel hump fat.

Kadim et al. [54] found that the mean saponification value of Arabian camel hump fat was 203 mg KOH/g oil. The lowest value (188.5 mg KOH g/oil) was recorded for citrus seed oil. Saponification value of Egyptian citrus seed oil ranged from 186.8 to 191.3 [11, 59]. The saponification values in citrus seed oils were noticed as being quite similar to those of corn (187-195), cotton seed (189-198), olive (184-196), pumpkin (185-198), soybean (188-195) and rice bran (179-195) oils [12, 69]. Blending camel hump fat with different levels of citrus seed oil caused significant reductions in saponification numbers. The decrease in the saponification number was gradually and significantly ($p \leq 0.05$) increased with the increase of the substitution levels with citrus seed oil. Saponification number decreased significantly from 203.1 mg KOH/g oil in camel hump fat to 200.25, 198.00, 194.46 and 191.49 mg KOH/g oil in camel hump fat mixed with 20, 40, 60 and 80% of citrus seed oil, respectively. Long chain fatty acids found in the fats have low saponification values because they have a relatively lower number of carboxylic functional groups per unit mass of the fat as compared to short chain fatty acids [70].

Iodine value

Iodine value is used to measure the unsaturation degree of fats and oils. According to this chemical parameter, the fats and oils are classified into three categories, i.e., drying oils (IV > 130), semi – drying oils (130 > IV > 100) and non-drying oils (IV < 100). The iodine values of camel hump fat (CHF), citrus seeds oil (CSO) and binary mixtures of them are shown in Figure 1E. Iodine values of native and blended oils varied from 63.50 to 100.09 gI_2/100g oil. Citrus seed oil had significantly ($p \leq 0.05$) the highest (100.09 gI_2/100g oil) iodine value. Therefore, citrus seed oil belongs to semi-drying oils. In contrast, the lowest iodine value (63.50 gI_2/100g oil) was recorded for camel hump fat; this finding may be due to its low unsaturated fatty acid content. Therefore, the camel hump fat can be classified as non-drying oil. Blending camel hump fat with different levels of citrus seed oil caused significant increases in the iodine values of the blended oils. As the amount of citrus seed oil increased in the oil blends, the iodine values increased proportionally. Iodine value increased significantly from 63.50 gI_2/100 g for camel hump fat to 93.02 gI_2/100g in camel hump fat blended with 80% of citrus seed oil. These increases in iodine value may be attributed to the increase in the portions of the unsaturated fatty acids in the blended oils (Tab.I).

CONCLUSION

The results of this investigation showed that blending camel hump fat with different levels of citrus seed oil reduced the content of saturated fatty acids, caused marked increases in the content of polyunsaturated fatty acids as well as an improvement in the physico-chemical properties of the blended oils.

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